Lecture 14
March 3, 2005

Know:

1. The nature of electric charge
2. Coulomb's law describing the electronic force.
3. The distinction between insulators and conductors.
4. The definition of electric field.
5. The definition of electric potential.

Understand:

1. How objects acquire charge.
2. The inverse square law dependence of electrostatic force on distance between charges
3. How to draw electric field lines
4. How to calculate electrostatic potential energy.
5. How to charge an object by induction.

The electric field created by a moving negative charge

A. points toward the charge.
B. points away from the charge.
C. describes concentric circles about the direction of motion.
D. points in the direction of motion.
E. points in the direction opposite to the velocity.

A metallic object has a net charge on it. For steady state conditions, the excess charge is located

A. on the bottom of the object .
B. on the surface of the object.
C. near the side closest to the North magnetic pole.
D. at the center of mass of the object.
E. at the top of the object.

Coulomb's Law

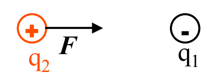
- Experiments by Charles Coulomb have shown that the electric force exerted by one charge upon another is proportional to the magnitude of the charges and inversely proportional to the square of the distance (r) between them.

$$F_e = k\frac{q_1 q_2}{r^2} \qquad k = 9\times10^9\, Nm^2/C^2$$

q_1 q_2 are the charges in Coulomb

- Like charges repel, opposite charges attract.
- If we have **more than 2 charges** we calculate the net force on an object using a **vector sum** of all forces.

Electric Field

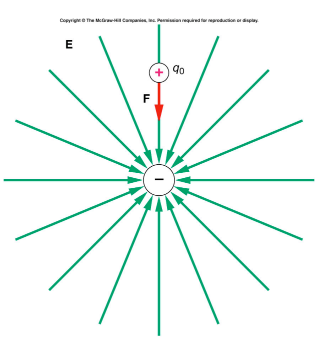


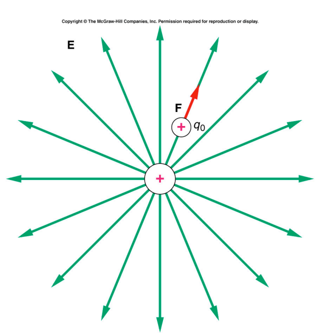
- Electrostatic forces act at a distance. In the above picture the charge q_1 is exerting a force F on the charge q_2.
- We can describe the electrostatic effect of a charge with the electric field .The electric field is the electric force that would be exerted on a positive unit charge, therefore the electric field due to q_1 is:

$$E = \frac{F}{q_2} = k\frac{q_1}{r^2}$$

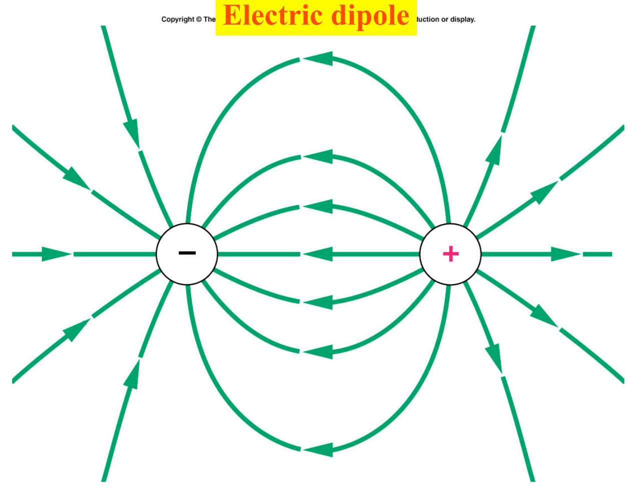
Electric Field Lines

- To visualize an electric field, we show the direction of the field with field lines:



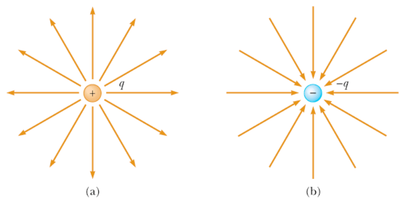


Electric dipole



Features of Field Lines

- Field lines start on positive charges and end on negative charges and nowhere else.



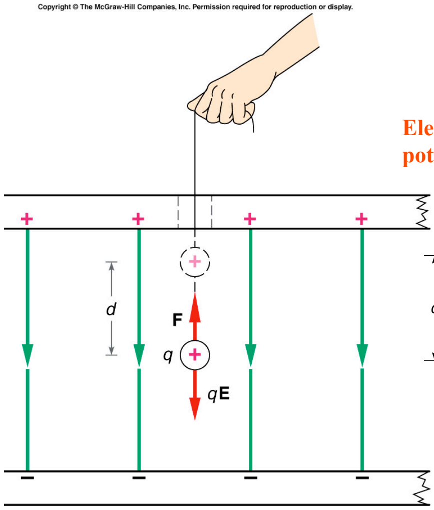
- The magnitude of the electric field is the density of field lines

Van de Graaf demo

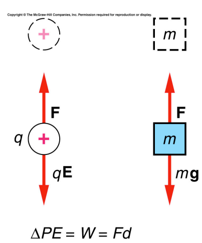
Electrical Potential

- The electrical potential (or voltage) at a given location in space is the amount of energy (work) required to move a unit test charge from infinity to that location.
- The Units of potential are thus Joules/Coulomb or Volts.
- The amount of work required to move a unit test charge from point a to point b is just the difference in potential.

$$W = \Delta PE = (V_b - V_a)q$$



Electric and Gravitational potential energy



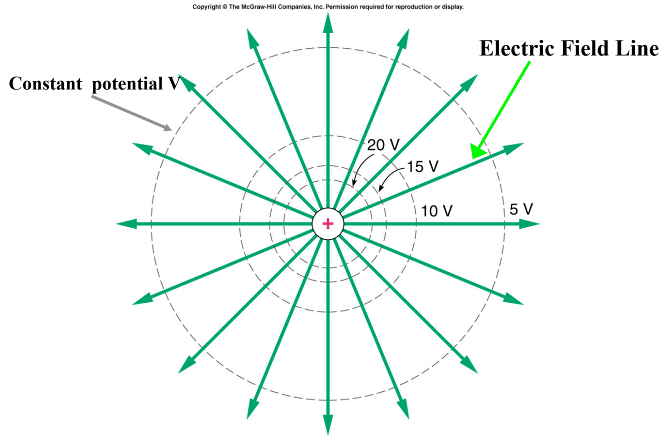
Electric Potential Energy

- Work done (by electric field) on charged particle is $W=Fd=qEd$
- Particle has gained Kinetic Energy
- Particle must therefore have lost Potential Energy $\Delta U=-qed$
- **Potential is Energy divided by test charge**
- SI Units of Electric Potential are J/C Alternatively called **Volts (V)**

Electrical Potential (cont.)

- It is a totally amazing fact that the work only depends on the difference in potential and not the path that the charge takes
- For example:
  - If the potential difference between two ends of a battery is 1.5V and you move 0.1C of charge from one end to the other, you do (0.1C)(1.5V)=0.15J of work.
  - If the potential difference between the two ends of the battery is 12V and you move 2C of charge across the battery, you do (12v)(2c)=24J of work.

The electric potential V increases as we move closer to a positive charge



1 Comparing the electrostatic force and the gravitational force we can say that
A. both have the same dependence on distance, both involve attraction and repulsion but the gravitational force is stronger.
B. both have the same dependence on distance, both involve attraction and repulsion but the electrostatic force is stronger.
C. both have the same dependence on distance, the electrostatic force can be either attractive or repulsive while the gravitational force is only repulsive, and the electrostatic force is weaker.
D. both have the same dependence on distance, the electrostatic force can be either attractive or repulsive while the gravitational force is only attractive, and the electrostatic force is stronger.
E. the electrostatic force falls off more rapidly with distance, the electrostatic force can be either attractive or repulsive while gravitation is only attractive and the electrostatic force is stronger.

2. Two equal charges repel one another with a force of 4.0×10^{-4} N when they are 10 cm apart. If they are moved until the separation is 5.0 cm, the repulsive force will be
A. 16.0×10^{-4}N. B. 8.0×10^{-4}N. C. 4.0×10^{-4}N.
D. 2.0×10^{-4}N. E. 1.0×10^{-4}N.

3. Three equal negative charges are placed at three of the four corners of a square. The direction of the electric field at the remaining corner of the square is
A. along a side of the square toward one of the charges.
B. along a side of the square away from one of the charges.
C. along the diagonal connecting this corner and another charge, away from the other charge.
D. D. along the diagonal connecting this corner and another charge, toward the other charge.
E. no direction, zero field

4. A capacitor consisting of two separated parallel horizontal plates has a uniform electric field directed upward. If a negative charge is placed exactly midway between the two plates, it will
A. remain at rest. B. be accelerated upward.
C. be accelerated downward. D. be accelerated to the right. E. be accelerated to the left

5. A uniform electric field has a magnitude of 10 N/C and is directed upward. A charge brought into the field experiences a force of 5.0 N downward. The charge must be
A. +50 C. B. -50 C. C. +0.5 C. D. -0.5 C. E. -2.0 C.

Motion in a Uniform E-Field

E-Field → Force → Acceleration

$$\vec{\mathbf{E}} \rightarrow \vec{\mathbf{F}} = q\vec{\mathbf{E}} \rightarrow \vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}}{m} = \frac{q\vec{\mathbf{E}}}{m}$$